Analysis of Fine Structures of Flows, Hydrography, and Fronts in Taiwan Strait

PI: Quanan Zheng
Department of Atmospheric and Oceanic Science,
University of Maryland, College Park, MD 20742
Tel.: (301) 405-8253 Fax: (301) 314-9482 e-mail: quanan@atmos.umd.edu

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LONG-TERM GOALS

The long-term goal of the project is to determine the fine structures of flows, hydrography, and fronts by analyzing a collection of in situ data and satellite data. The in situ data provide a dual purpose: the description of conditions as they exist, and the verification and validation of the results from the satellite data analysis and dynamical analysis.

OBJECTIVES

(1) To resolve the fine structures of the flow field, (2) To determine the hydrodynamics and hydrography across the fronts, and (3) To examine the effects of the Taiwan Island to the fine structures and fronts under different forcing conditions. The tasks serving these objectives include the analysis of observational data from moorings and cruises, the use of an inverse analysis and extraction of flow field using Synthetic Aperture Radar (SAR) for fine structures, and the analysis of AVHRR/MODIS SST and MODIS/SeaWiFS ocean color parameters in the identification of the fine structures.

APPROACH

1) Field data analysis. The field data are used to describe the fine structures of flows, hydrography, and fronts, and examine the effects of the bathymetry and morphology on the fine structures to achieve the objectives. The horizontal and vertical structures, the effect of various waters of contrasting characteristics under seasonal wind conditions, the effect of Taiwan Island, and the effect of the generally shallow strait with sharp depth changes at near the northeast and southeast openings of the strait are major targets. Recently measured CTD data and historical XBT/AXBT data are used to determine the vertical thermal structure in the study area. The historical data are obtained from NOAA archives, which are in the public domain.

2) Satellite images. Satellite SAR is the most powerful sensor for ocean remote sensing because of its all weather, all day abilities, and high spatial resolution. The spatial resolution of the state-of-the-art satellite SAR images reaches 20 – 30 m, and the swath width reaches 100 – 450 km. These specifications match the requirements for observing the ocean internal waves with a spatial characteristic scale within a range from 0.1 km to 10 km. The SAR images used for the project were taken by the ERS-1 and 2, the RADARSAT-1 and 2 satellites.

3) Data processing methods. TECPLOT and GIS software packages are used for the visualization of the results from the analyses of the in situ data. These results will serve not only for the description and

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quantification of the fine structures, but also for the validation and verification of the analysis of satellite data including the algorithms of the inverse analysis of flow field using the satellite SAR images. Commercialized image processing software packets will be used for imagery enhancement, orthorectification, filtering, and data extraction.

4) Theoretical analysis. The objectives of theoretical analysis are to understand the nature, physics, mechanism, and laws of variation of the studied process, to derive unknown geophysical parameters using parameters and information derived from SAR image interpretation as inputs, to analyze the relation between the studied process and the surrounding environment, and to predict the future development of the studied process.

Dr. Quanan Zheng serves as a PI for research in University of Maryland. Zheng focuses on data collection, satellite image interpretation, and the theoretical analysis.

WORK COMPLETED

1) Cruise data analysis and numerical modeling. We continue to analyze the cruise CTD data collected in Taiwan Strait in July 2005 and June 2006 [Chen et al., 2005]. The low salinity tongue found from the cruise data last year has been simulated by a numerical model.

2) Observation and dynamical analysis of vortex trains in the straits. The vortex trains generated by the interaction between current and strait topography are a kind of fine flow structures in the strait. A case study for the Luzon Strait has been done. We will continue to analyze the case of Taiwan Strait.

3) Paper preparation. Partly supported by this project, six papers (see **PUBLICATIONS**) have been prepared and submitted to international-circulated and peel-reviewed journals. Three have been published, and another is in press. Three presentations were given in the academic conferences (POSEC 2006, the Fourth International Ocean-Atmosphere Conference, and the NLIWI 2007 meeting), respectively.

RESULTS

1) Cruise data analysis and modeling.

The cruise data collected in July 2005 and June 2006 are continuously analyzed [Chen et al., 2005]. From the cruise data, a low salinity tongue sandwiched by high salinity waters on both shallow and deep water sides in Taiwan Strait was found as shown in Figure 1. The low salinity tongue runs southwest-northeastward along 40-50 m isobaths. The tongue axis is located at an offshore distance of about 60 km and generally parallel to the direction of coastline. Defining 32 psu isohaline as the boundary of the low salinity tongue [Wu, 1989], the maximum width of the tongue at the surface layer (depth of 5 m) reaches 70 km. The water tongue tip reaches 23.2ºN, 118.3ºE. The water tongue root is located on the southwest side of the survey area, where the lowest salinity is only 27 psu, implying that the low salinity water originates from somewhere southwest of the survey area. Meanwhile, the existence of strong salinity fronts implies that a jet-like current has to serve as low salinity water supplier to maintain the existence of low salinity tongue [Zheng et al., 1982; Hong et al., 2006].

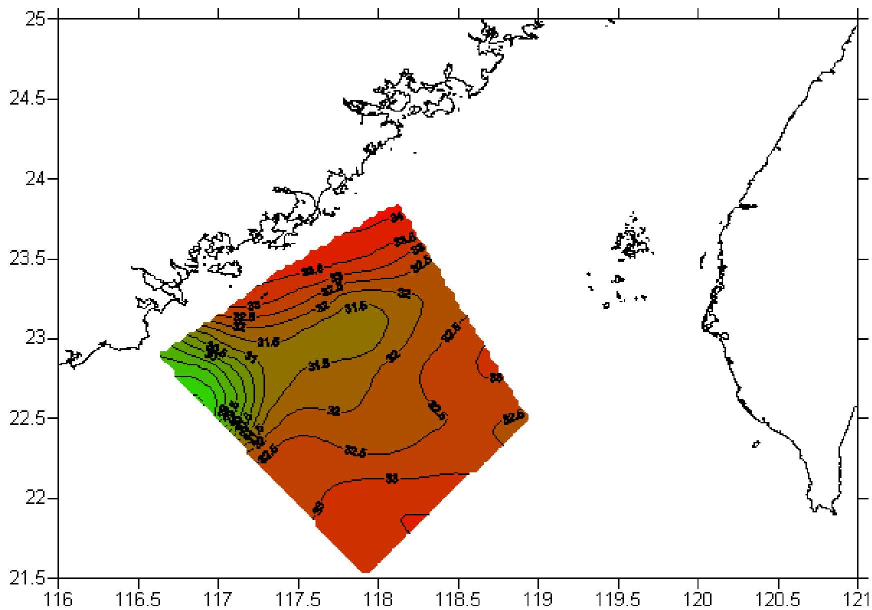

Figure 1. Two-dimensional distribution maps of the salinity at depths of 5 m derived from the 2005 summer cruise data by interpolation methods.

In order to explain the observations and the low salinity tongue, a numerical model is developed. The results are shown in Figure 2. One can see that the model results agree with the observations well, and further show that the low salinity water originates from the Pearl River Estuary and extends passing through Taiwan Strait.

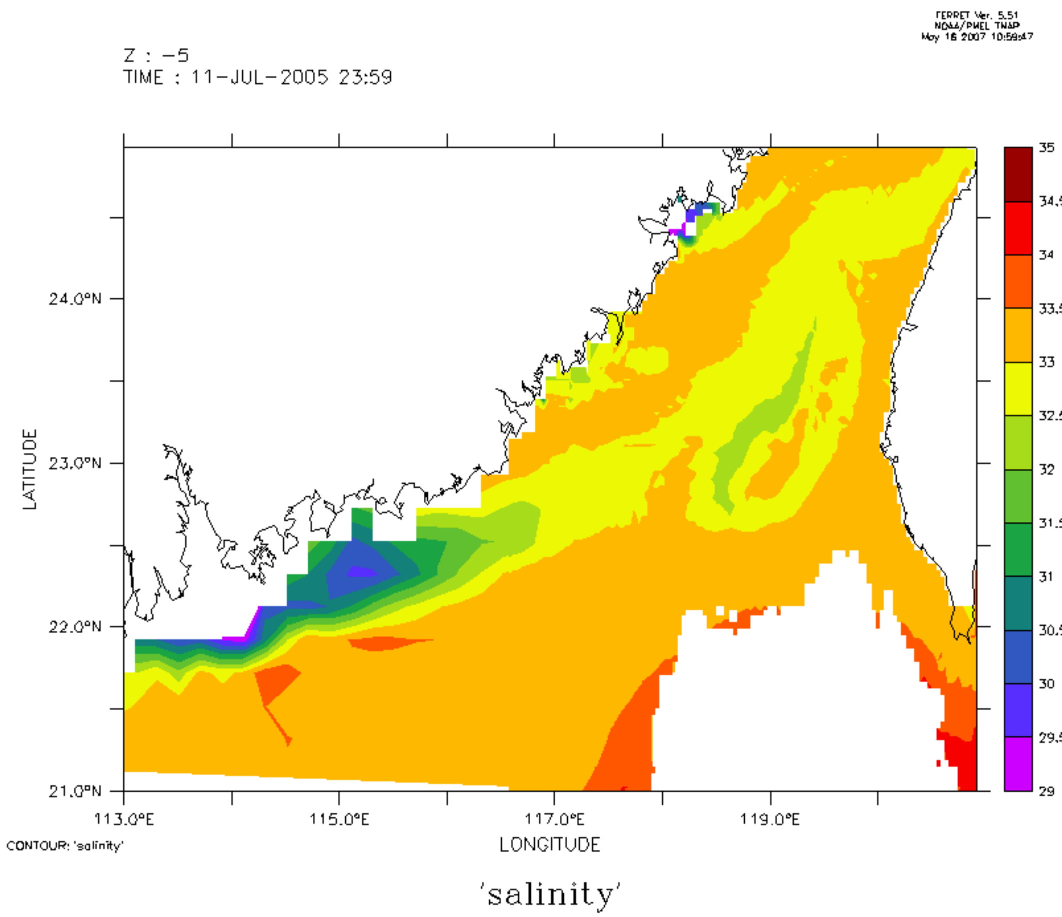

Figure 2. Modeling results of two-dimensional distribution of the salinity at depths of 5m in summer in Taiwan Strait.

2) Dynamical analysis of vortex trains in the straits.

The ocean vortex trains have been observed in Taiwan Strait and Luzon Strait. Two cases of ocean vortex trains in the Luzon Strait are analyzed. The case of Taiwan Strait will also be analyzed. The first train of three cyclonic vortices in the Luzon strait showed up on drifter trajectories from 20° to 20.5°N and from 120° to 121°E, and the second, consisting of five pairs of cyclonic-anticyclonic vortices, occurred on the upstream side of the first one from 19.5° to 20.0°N and from 121.0° to 122.0°E and showed up on the ASAR images acquired on 19 November 2006 as shown in Figure 2. The total length of the vortex train axis reaches about 250 km. All vortices propagate northwestwards (~315º TN). The mean angular velocity is $(2.07 \pm 0.18) \times 10^{-5}$ s^{-1}. Theoretical models of ocean vortex radar image derived from radar imaging theories are used to extract dynamical parameters from ASAR imagery signatures, which include the distance between two consecutive vortices and that between two rows of vortices of (22.6±1.9) km and (8.2±1.2) km, respectively, the maximum rotational velocity radius as 4.70 km, and the vortex rotational angular velocity $3\times10^{-5}s^{-1}$. Dynamical analyses give the mean velocity of the current of 0.65 ms^{-1}, and the propagation velocity of the vortex 0.58 ms^{-1}. The vortex shedding rate is estimated as 2.57×10^{-5} s^{-1}. The Reynolds number is estimated as 50 to 500. For the individual vortex and the vortex train, the Rossby numbers are *O*(0.4), and *O*(0.5), respectively, implying that both vortex and vortex train observed in the Luzon Strait have a sub-mesoscale nature. This study also reveals a strong current with an average surface current velocity of around 0.7 ms^{-1} and the direction of around 315º TN flowing directly from the Pacific to SCS passing through the southern Luzon Strait. The mean flow velocity can be calculated using methods developed in this study and OVT dynamical models.

IMPACT/APPLICATIONS

The results of this project will provide the users fine structures of ocean circulation in Taiwan Street, and will benefit the broader oceanographic community, ocean engineering industries, underwater navigation and operational users. The results may also serve as a basis for empirical, theoretical, and numerical prediction models of ocean circulation in the Taiwan Street. The results will further reveal SAR imaging mechanisms and be used for SAR image interpretation.

RELATED PROJECTS

This project and the project of Grant Number N00014-05-1-0605 at the Louisiana State University (PI: Dr. Chunyan Li) are two separately funded components of the same project. The PI of this project serves as a PI for an ongoing ONR PO project titled “Satellite Synthetic Aperture Radar Detection of Ocean Internal Waves in the South China Sea”. The study areas of two projects are immediately adjacent. Therefore, two projects sometimes share the same data resources of field observations.

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